CMP process development for Cu/low-k based interconnect systems

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1 Introduction

CMP technologies are widely established for the realization of interconnect systems in advanced microelectronic devices. Nevertheless, ongoing research and development is necessary in order to meet the requirements of future device generations. The new (porous) low k materials need CMP processes with a very low down force due to their weak mechanical strength. In addition, porous low k materials require a cap layer whose selectivity within the polishing processes must be ensured. The continuous down scaling requires extreme low values for dishing and erosion. Moreover, slurries with a lower abrasive size or abrasive free slurries are needed for polishing of small features. Within the last year first investigations concerning the polishing of copper-barrier-stacks on different porous low-k material stacks have been performed at Center for Microtechnologies.

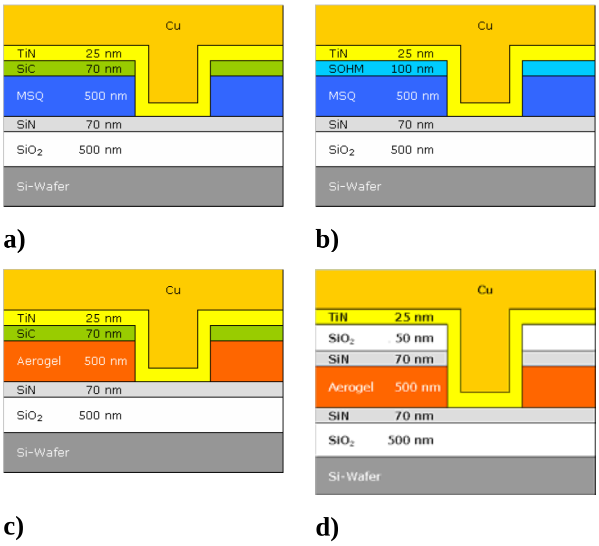

Fig. 1: Prepared layer stacks for CMP investigations
a) Porous MSQ with SiC cap layer
b) Porous MSQ with spin-on hard mask (SOHM)
c) Aerogel with SiC cap laye
d) Aerogel with SiO_2/SiN cap layer

2 Experimental

As low-k dielectrics porous silicon oxide (aerogel) as well as porous methylsilsesqui-oxane (MSQ) have been investigated. The used cap layers were SiC, SiO_2/SiN, and a MSQ-based spin on hard mask (SOHM). Four different stacks have been prepared as shown in figure 1.
Polish rate and selectivity were determined using blanket wafers with the appropriate films on top. The critical factors for the polishing process (dishing, erosion, defects, homogeneity) were examined on the patterned wafers by optical microscopy, SEM (plain view and cross section), and topography measurements after polishing. The polishing experiments have been carried out using two different sets of chemicals provided by two suppliers. Set #1 (supplier A) consists of one copper slurry (suitable for bulk removal and Cu-clearing) and one barrier slurry (designed for TaN/Ta, applicable for Ti/TiN). Set #2 (supplier B) consists of one Cu-bulk slurry, one Cu-clearing slurry, one barrier slurry (TaN/Ta, Ti/TiN), and a special pad cleaning solution.

3 Polish rates and selectivity

Chemicals set #1

The polish rate of the Cu slurry was determined with 200…350 nm/min (depending on the pattern factor) at 2 psi down force and 100 ml/min slurry flow. The selectivity of the Cu slurry regarding barrier and cap layer materials is summarized in table 1 (left part). For TaN/Ta barriers the selectivity is high as desired. In case of Ti/TiN however, the Cu slurry shows nearly no selectivity. Moreover, for the SOHM a serious mechanical impact was found (scratches). The barrier slurry was used at 1 psi down force and 200 ml/min slurry flow. The obtained polish rates (see table 1 right part) show a relatively low selectivity to Cu as well as to SiN and SOHM.

Tab. 1: Selectivity of Cu slurry and polish rates of barrier slurry from supplier A

Cu slurry Selectivity		***Barrier slurry*** Polish rate [nm/min]	
Cu : TaN/Ta	> 100	TaN	20 … 50
Cu : Ti/TiN	2	TiN	20 … 50
Cu : SiC	> 250	Cu	5 … 20
Cu : SiN	> 100	SiC	0.8
Cu : SOHM	10	SiN	30
		SOHM	30 … 40

Chemicals set #2

The polish rates for bulk and clearing slurry were determined with 900…1000 nm/min and 600…650 nm/min, respectively. The polish parameters for both slurries were 2 psi down force and 200 ml/min slurry flow. Table 2 shows the obtained selectivity results.

Tab. 2: Selectivity results for Cu bulk and clearing slurry from supplier B

	bulk slurry	***clearing slurry***
Cu : Ti/TiN	> 14	> 10
Cu : SiC	> 55	> 600
Cu : SiN	> 110	> 60
Cu : SOHM	∞	∞

For both slurries the selectivity regarding Ti/TiN is low, but better than for the Cu slurry of supplier A. Regarding all dielectric cap layers both slurries exhibit an excellent selectivity. For the SOHM material once again scratches have been found. Table 3 summarizes the polish rates for the barrier slurry.

Tab. 3: Polish rates for the barrier slurry of supplier B (in nm/min)

TiN	150…200	SiC	3…4
Cu	40…50	SiN	6…8
SiO_2	7…8	SOHM	22…25

4 Polishing of Cu/TiN layer stacks on low k materials

The prepared layer stacks (fig. 1) were polished. Fig. 2 shows a typical result for the porous MSQ material after the polishing with chemicals set of supplier A. Due to the low selectivity of that Cu slurry regarding the TiN barrier a two step polishing has been applied. Platen 1 was used for Cu bulk removal and platen 2 for Cu clearing and barrier removal. The porous material has been found unchanged after polishing. Neither mechanical damages nor film delamination could be observed. Dishing values have been found in the range of 30…50 nm, measured on 10 µm wide lines with 4 µm spaces. The typical erosion was below 20 nm. No differences were found between the SOHM and SiC cap layer.

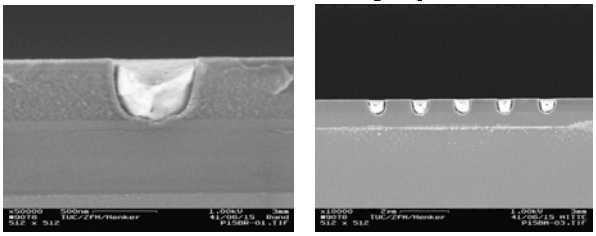

Fig. 2: SEM cross section after polishing a Cu/TiN layer stack on porous MSQ with SOHM cap layer (left picture) and with SiC cap layer (right picture)

Different results were obtained for the aerogel low k material. Polishing of that material results in a nearly complete loss of the dielectric stack in areas with a low pattern density. In areas with a high pattern density the low k stack seems to be unchanged as shown in figure 3. This behaviour was found independent from the consumables as well as from the used cap layer. This material definitively needs dummy Cu patterns or even lower down force to be polished defect-free.

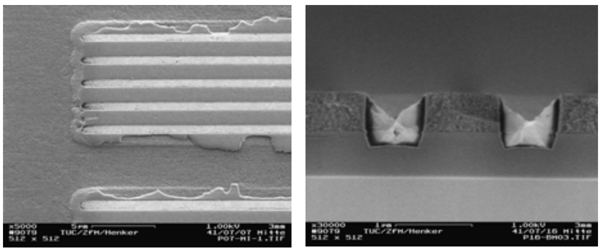

Fig. 3: SEM cross section after polishing a Cu/TiN layer stack on aerogel: delamination in areas with low pattern density (left picture), unchanged material between narrow structures (right picture)

4 Summary and outlook

The performed investigations were very first approaches to the polishing of low-k based interconnect systems. Promising results could be obtained with the porous MSQ material. For that material the next steps will be to figure out the critical down force and a further minimization of dishing and erosion.

Acknowledgement

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